FORECAST OF OCCURRENCES OF EARTHQUAKES IN THE NORTH-WESTERN PART OF THE KINKI DESTRICT

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FORECAST OF OCCURRENCES OF EARTHQUAKES IN THE NORTH-WESTERN PART OF THE KINKI DISTRICT

By

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Abstract

Summations and considerations of data in seismology and geodesy are practised in order to make the plan of the forecast of the occurrences of earthquakes in the north-western part of the Kinki District.

The author finds some interesting areas on the study of the forecast the occurrence of earthquakes.

1. Introduction

There are important parts of civilization in the north-western part of the Kinki District. Unfortunately, there have been many destructive earthquakes in this district. It is important to know the activity of earthquakes in the near future in order to devise a plan to protect the development of the civilization which our ancestor have constructed for long times. These plans have been carried out in the offices of the some prefectures. Because anyone is rarely suffered from an earthquakes, but many peoples in these prefecture are suffered from it even in near future.

The trials of the forecasting of the occurrences of earthquakes are dicussed founded on the process of destructive earthquakes in the past time, the seismicity in the present time, the crustal movements and so on in this paper.

2. The distribution of earthquakes

The epicenters of the earthquakes which have rocked this district have been in three zones and in a few regions; they are off the coast of the Pacific Ocean (off Nankaido and off Tonankaido), along the coast of the Japan Sea, around the zone from the river Yodo to the western coast of Lake Biwa, and in the Harima block.

There are three groups of earthquakes whose the greatest magnitudes were 8.6, 8.4 and 8.1 off the coast in the Nankaido or Tonankaido. The group of $M=8.1$ (in 1099, 1605, 1944 and 1946 A.D.) have rocked the weakest ground and damaged houses in this district by their oscillations. The ordinary group of gigantic earthquakes off Nankaido is that of $M=8.4$ (in 684, 1096, 1361, 1707 and 1854 A.D.). The earthqueke of this group has rocked most of the weak ground in this district and damaged buildings, and tsunami struck the eastern coast of Osaka Bay and the lower the river Yodo and its branch rivers. That of $M=8.6$ (in 887 and 1498 A.D.) caused the collapse of buildings and the human works at most area in this district, and gigantic tsunami struck all the coast of the Osaka Bay.

The greatest magnitude of an earthquake on the coast of the Japan Sea was about 7.5, and such an earthquake has occurred about every 1000 years. The epicenters of these earthquakes have ranged along the coast of the Japan Sea except a few areas. The destructive earthquakes of $M \doteqdot 7.5$ have occurred every about 1,000 years (in 1185 and 1662 A.D.); and those of $M \doteqdot 7$ have occurred about every 500 years (in 599, 734, 938, 1596 A.D.); and those of $7<M<6$ have occurred in about every 100 years in the zone from the Osaka Bay to the western side of Lake Biwa. The greatest magnitude of them in the Harima Block was 7.9 in 868 A.D. It seems that the origin of this earthquake was on the same line of the geological structure with that of Kinosaki in 1925.

The intensities near the origins of these earthquakes on the land were more than

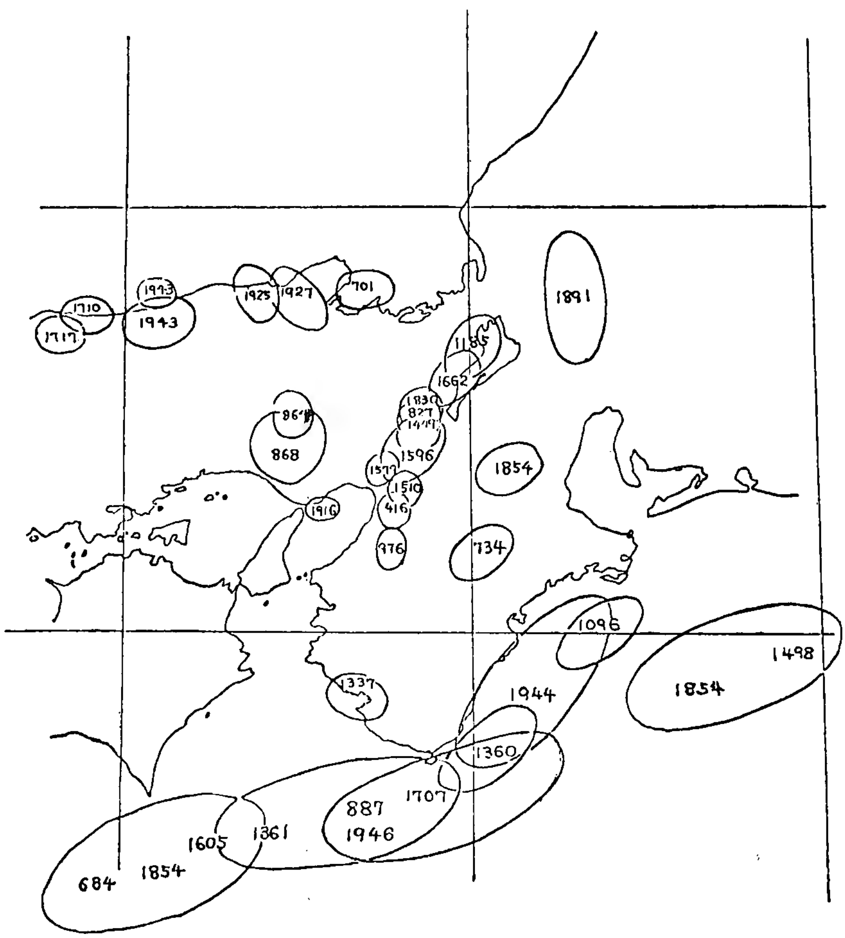
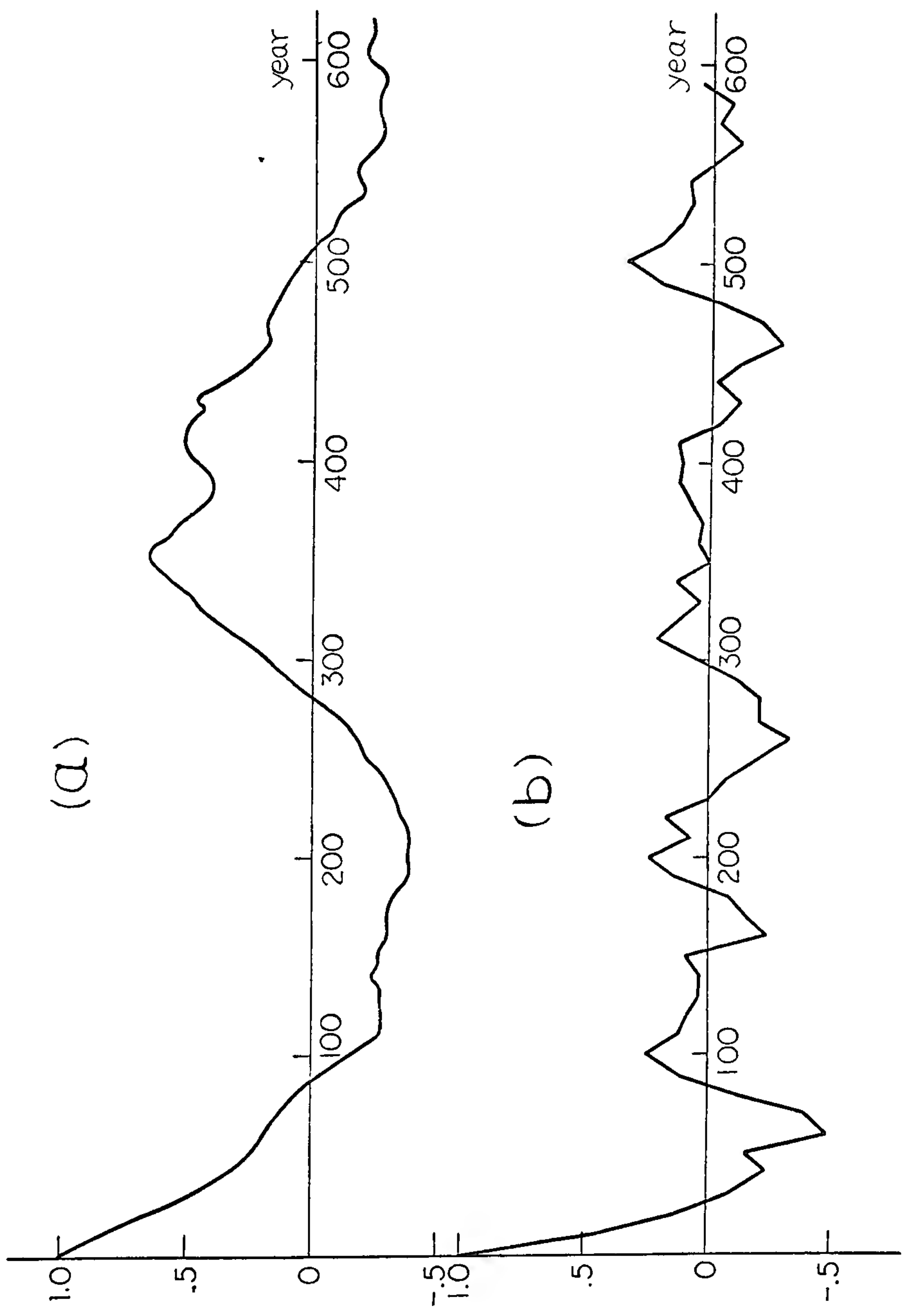


Fig. 1. Distributions of origins of destructive earthquake.


(a)
(b)
year
year
100
200
300
400
500
600
1.0
.5
0
-.5
1.0
.5
0
-.5

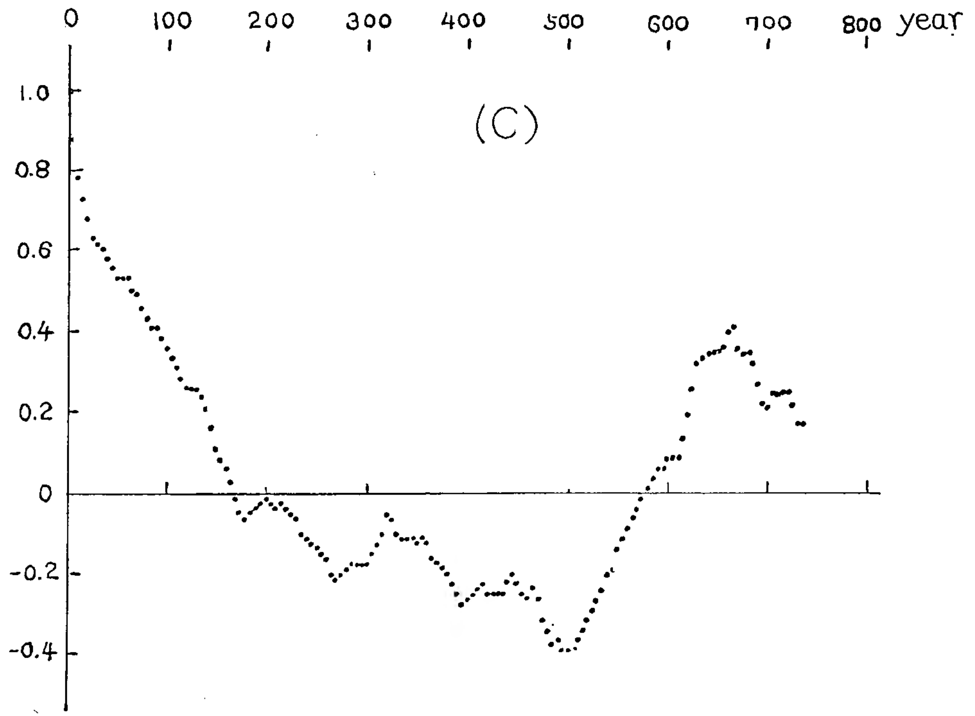


Fig. 2. Auto-correlation curves of the time series of the occurrences of earthquakes in the Japanese zone of the Pacific Ocean (a), in Kyoto Prefecture (b) and in Hyogo Prefecture (c).

7, and have been accompanied by very violent damage, because these focal depth were very shallow.

Fig. 1 shows these seismic origins in and near this district.

3. The time series of the occurrence of destructive earthquakes

The auto-correlations of the time series of the occurrences of destructive earthquakes in the prefectures of Kyoto and Hyogo, and the Japanese zone of the Pacific Ocean are calculated, and shown in Fig. 2 (a), (b) and (c). These curves in Hyogo and the zone of the Pacific Ocean have remarkably long periods. But, that in Kyoto does not have so remarkable period, and has the pretty amplitudes in the periods of 100 and 500 years. If it eliminates the long periods of more than 200 years, about

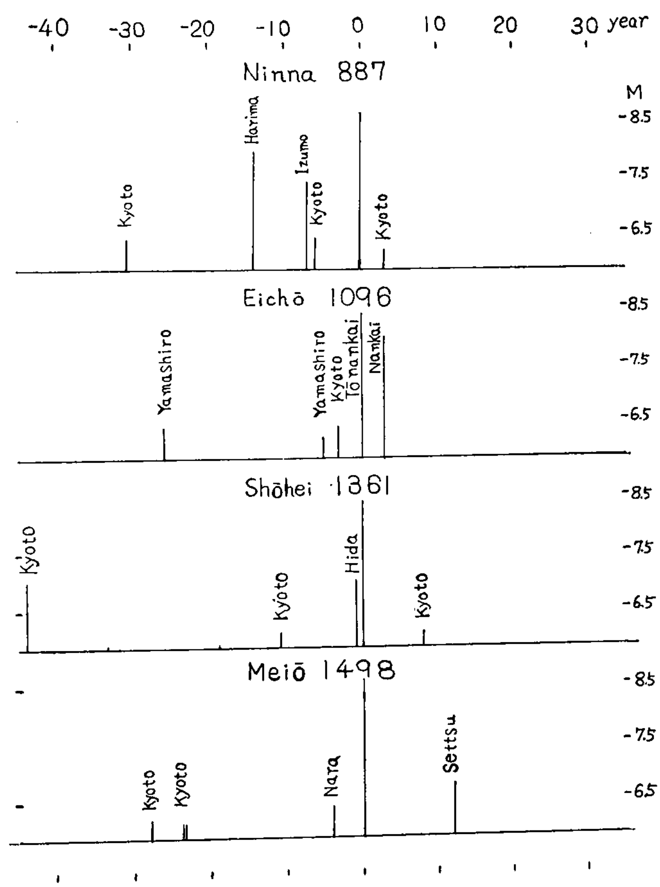


Fig. 3 (a). The relation between the times of the occurrences and magnitudes of the earthquakes in the northern part of the Kinki District and those off Nankaido.

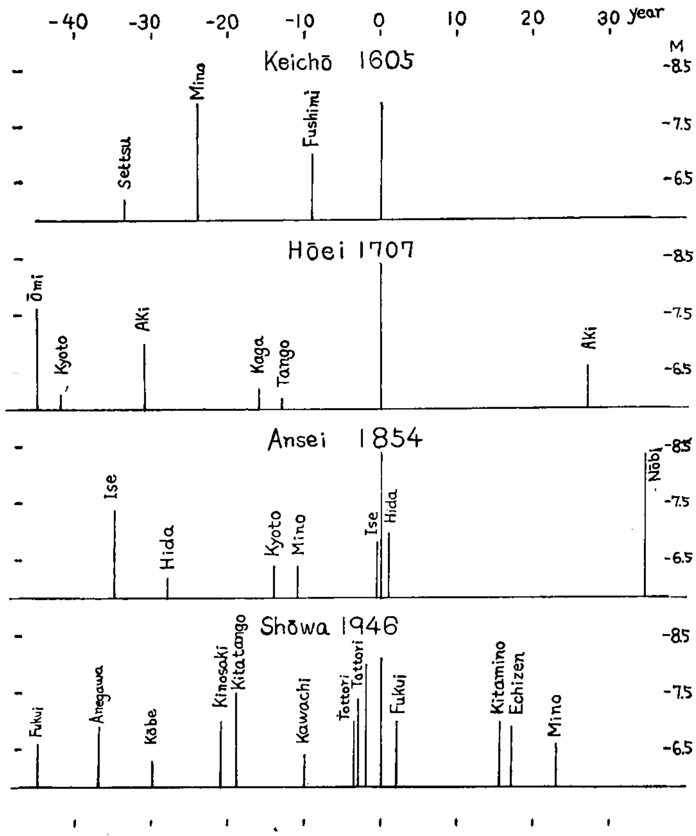


Fig. 3 (b). The relation between the times of the occurrences and the magnitudes of the earthquakes in the northern part of the Kinki District and those off Nankaido.

100 year's period's waves would appear clearly. This result shows that the correlation between the occurrences of the earthquakes in this district and that in the Japanese zone of the Pacific Ocean is high.

It is remarkable that the destructive earthquakes in this district have occurred within the period of about 30 years before the occurrences of the gigantic earthquakes off the Nankaido or Tonankaido. Fig. 3 (a) and (b) show the relation between the times of the occurrences and magnitudes of the earthquakes in this district and those off Nankaido or Tonankaido. In Fig. 3, the abscissas show the time of year from the times of the occurrences of the Nankaido Earthquakes, and their centers are the time of the Nankaido Earthquakes. The heights of the spectrum show the seismic magnitude in Fig. 3.

The mechanism of the earthquakes in the zone of the Pacific Ocean adjusent Japan Island is explained well, and their periodicity is regular too. So, we can estimate the time of occurrence of gigantic earthquakes off Nankaido, that is repeated about every 100 years. We cannot estimate the time of the occurrence of the earthquake in one prefecture, but we can estimate the time of about 30 years in this district which has three or four prefectures.

On the other hand, it is calculated statistically that the probabilities of destructive earthquakes within the coming ten years are about 20% in Hyogo Prefecture and 30% in Kyoto Prefecture, respectively by using the time series of the occurrences of earthquakes.

4. Recent activity of earthquakes

Fig. 4 shows the distributions of the epicenters of the earthquakes which were noted at the observatories of the Japan Meteorological Agency 1885 to 1971. We can see three large blanks of the epicenters in this figure. They are in the center part of Hyogo Prefecture, and the northern and the southern sides of Kyoto Prefecture. If there are the largest earthquakes in these blanks, the magnitude of the largest earthquakes which are able to occur in these blanks are calculated as 7.8 in Hyogo, 7.6 in the north and 7.4 in the south of Kyoto. Such a blank is found over Biwa too.

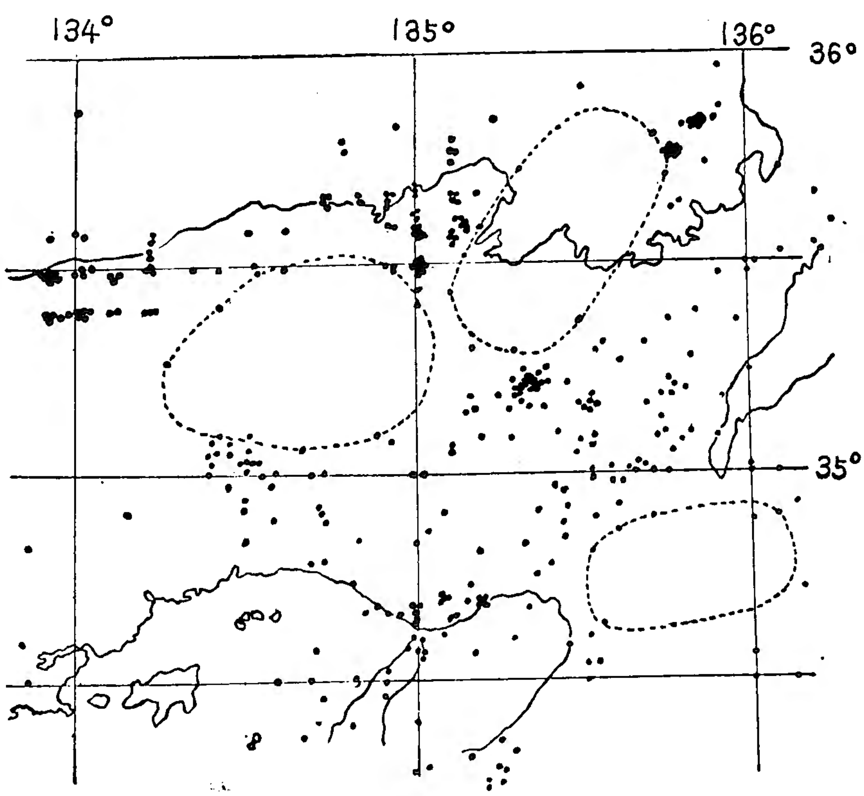


Fig. 4. The distributions of the epicenters in recent years.

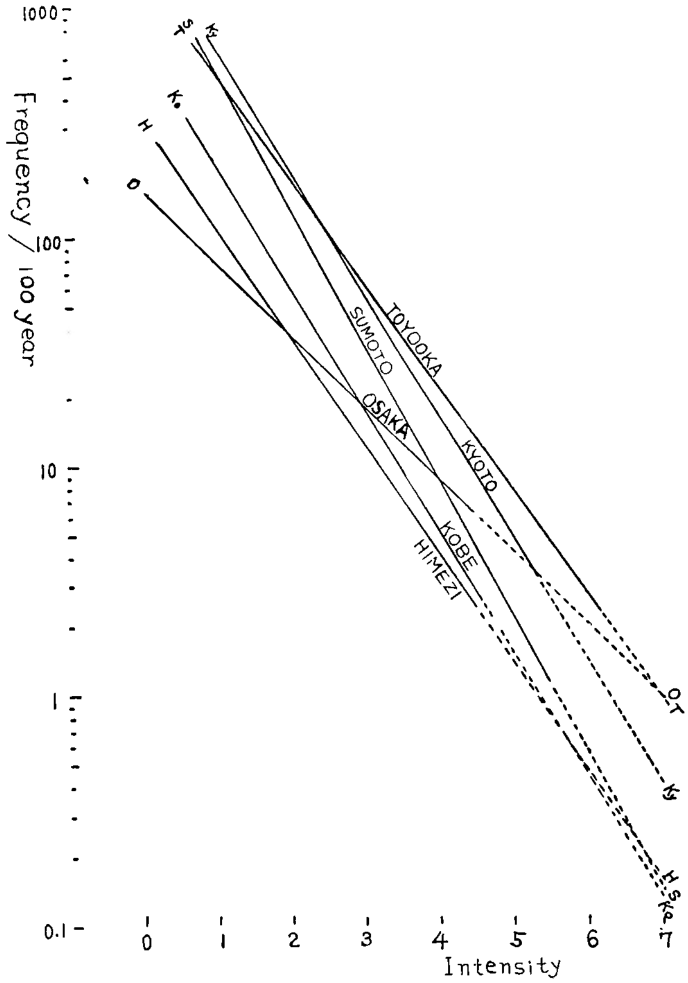


Fig. 5. The frequency ratios per 100 years of seismic intensities.

The frequencies ratio of the intensities at Kyoto, Kobe, Osaka, Toyooka, Sumoto and Himeji per 100 years are shown in Fig. 5. In this figure, the broken lines of the each curves show that the earthquakes of intensities on the broken lines have not occurred yet for the periods when the observations were performed. We may estimate the probabilities of occurrences of stronger earthquakes which have not been observed.

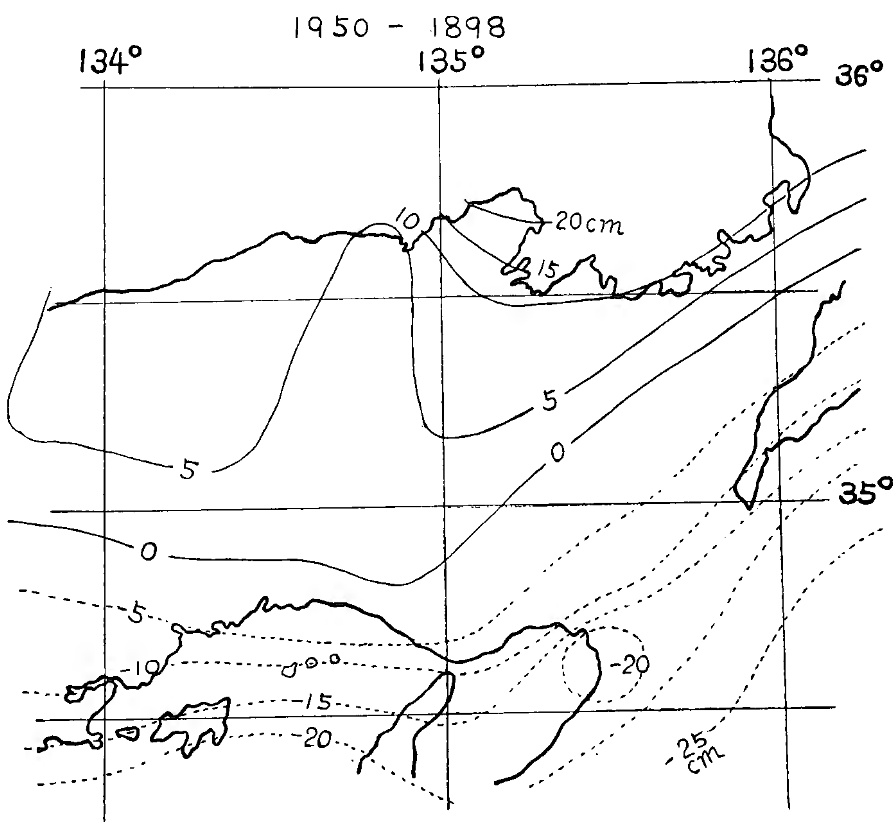
5. Crustal Movements

Surveys of crustal movements have been carried out by means of precise levellings about every 10 years by means of triangulations twice for fifty years by the Geographical Survey Institute of Japan.

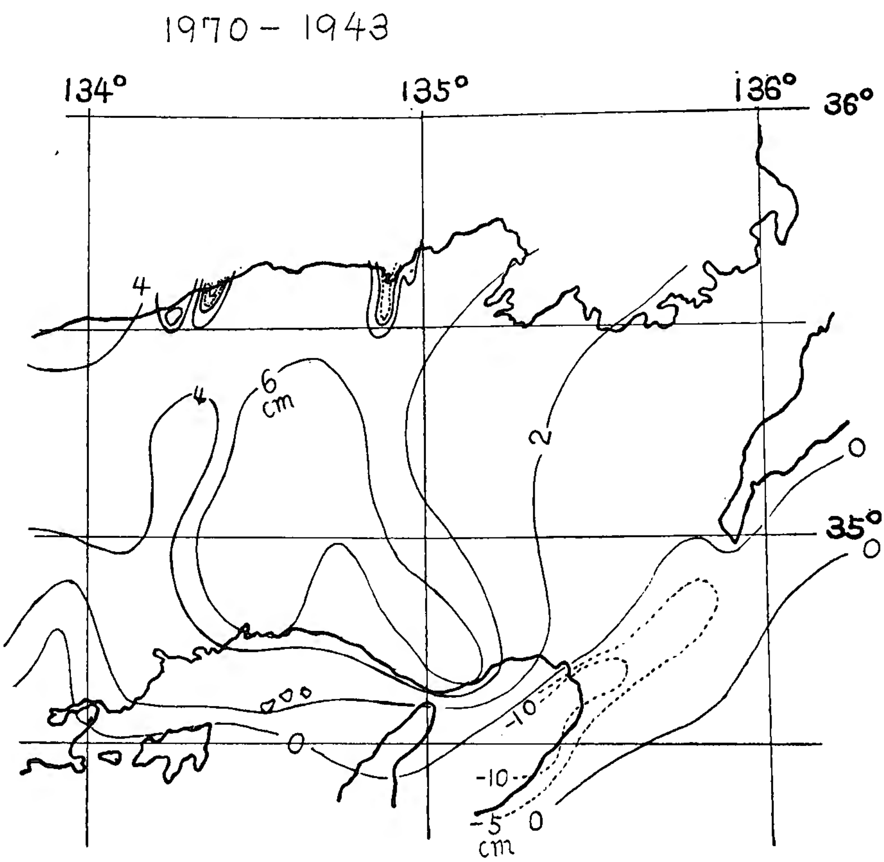
Fig. 6 (a) (G.S.L. [1960]) and (b) shows the vertical displacements of the crust in this district or the periods from 1898 to 1950 and from 1943 to 1970. They show that the crust around the Seto Sea, Osaka Bay and the river Yodo had been subsided, and the northern part of this district had been risen in the former period. Recently, the crust of Hyogo Prefecture and the northern part of Osaka have been rising, those around and the south part of Kyoto have continued to subside. It is known also that the western side of Lake Biwa has been rising for the both periods.

Fig. 7 (a) and (b) shows the vectors of the horizontal displacements of the first triangulation points, and the main strains analysed by use of these horizontal displacements (T. Harada et al. [1969]). According to these figures, it seems that the crusts have been compressed greatly in the areas of Kitatango and Tottori where the great earthquakes have occurred. And we can see small expansions of the crust in the southern part of Hyogo Prefecture, the northern part of Osaka Prefecture and most of Kyoto Prefecture.

We understand that compressions of the crust show recoveries after the earthquakes, and expansions are related to activities which may be connected to the oc-



(a)



(b)

Fig. 6. The vertical displacements of the crust for the periods from 1898 to 1950 (a) and from 1943 to 1970 (b).

currences of earthquakes. They say that compressions of the crust are in the subsiding areas, and the expansions are in the rising areas.

The observations of the crustal extensions at Osakayama (Otsu) have shown contractions in the direction of S38°W, and have done the extensions in S52°E, nowadays. Fig. 8 shows the crustal extensional curves at Otsu. (I. OZAWA [1971]).

Figs. 9 and 10 show the distributions of the Bouguer anomaly of the gravity and the declination component of the earth magnetism studied by C. Tsuboi et al. (1956), and G. S. I. (1956, 1960), respectively. The local anomaly found in these figures seems to have a relationship to future earthquakes too.

Acknowledgements

Some parts of this report have been summarized by the charges of prefectures of

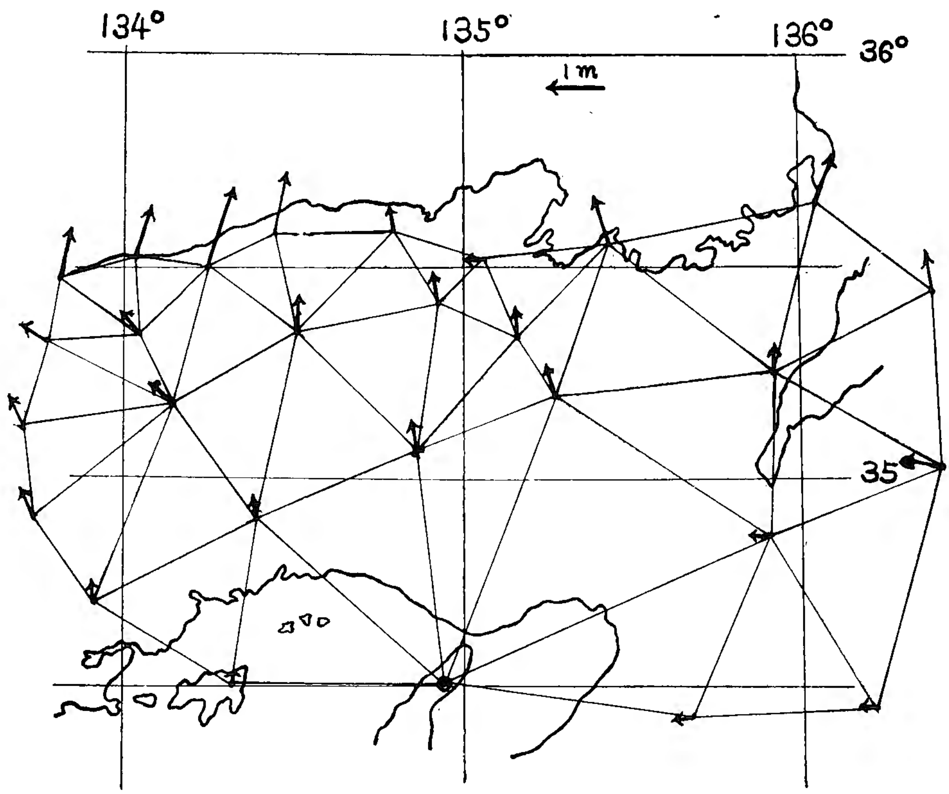


Fig. 7 (a). The distributions of the vectors of the horizontal displacements.

Kyoto and Hyogo and of the Kyoto city. The author wishes to express many thanks to these offices. He expresses also many thanks to the Japan Meteorological Agency and the Geographical Survey Institute who furnished data for this report.

References

Geographical Survey Institute, 1956. The second order magnetic survey in Chubu and Kinki District. J. Geod. Soc. Japan, Vol. 3, pp. 59–62.

Geographysical Survey Institute, 1960, Report on the levelling in Japan for the period from Jan. 1957 to Dec. 1959, J. Geod. Soc. Japan, Vol. 6, pp. 62–63, and Fig. 2.

Geographical Survey Institute, 1961, The second order magnetic survey in Chugoku, Shikoku and Kyushu Districts, J. Geod. Soc. Japan, Vol. 7, pp. 39–45.

Harada, T. and N. Izawa, 1969, Horizontal Deformation of the crust in Japan, J. Geod. Soc. Japan, Vol. 14, pp. 101–105.

Ozawa, I., 1971; Observations of the secular and annual changes of the crustal strains, Contr. Geophy. Inst., Kyoto Univ., No. 11, pp. 205–212.

Tsuboi, C., A. Jitsukawa, and H. Tajima, 1956. Gravity survey along the lines of precise levels throughout Japan by means of a Worden gravimeter, Bull. Earthq. Res. Inst., Tokyo Univ., supplementary volume, V.

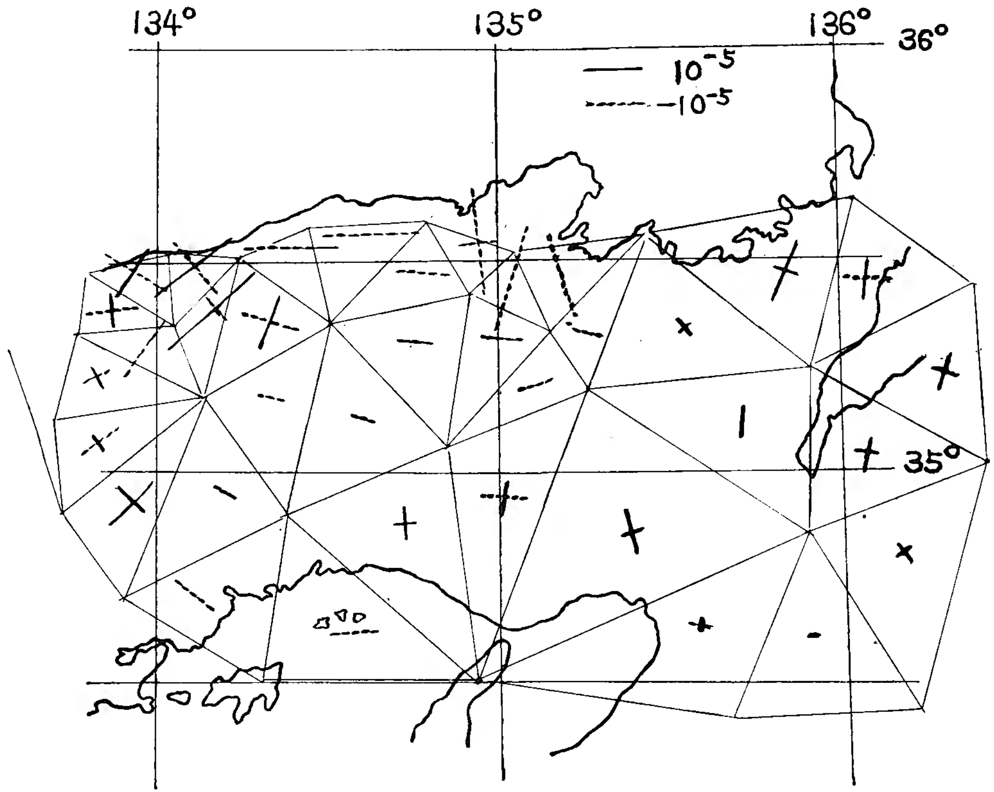


Fig. 7 (b). The distributions of the main strains, segment of full line shows the extension, and that of broken line shows the contraction.

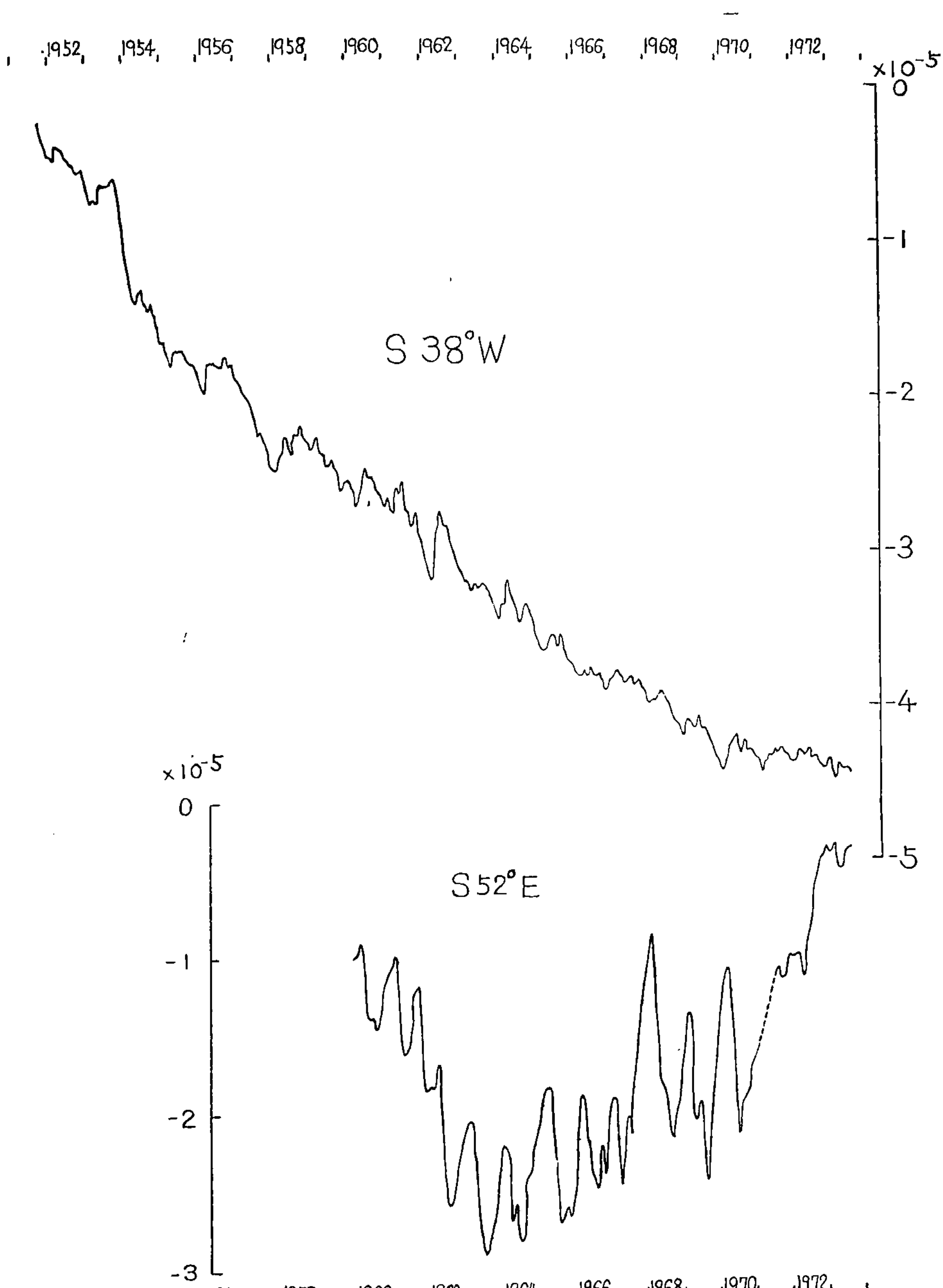


Fig.8 . The crustal extensional curves at Otsu.

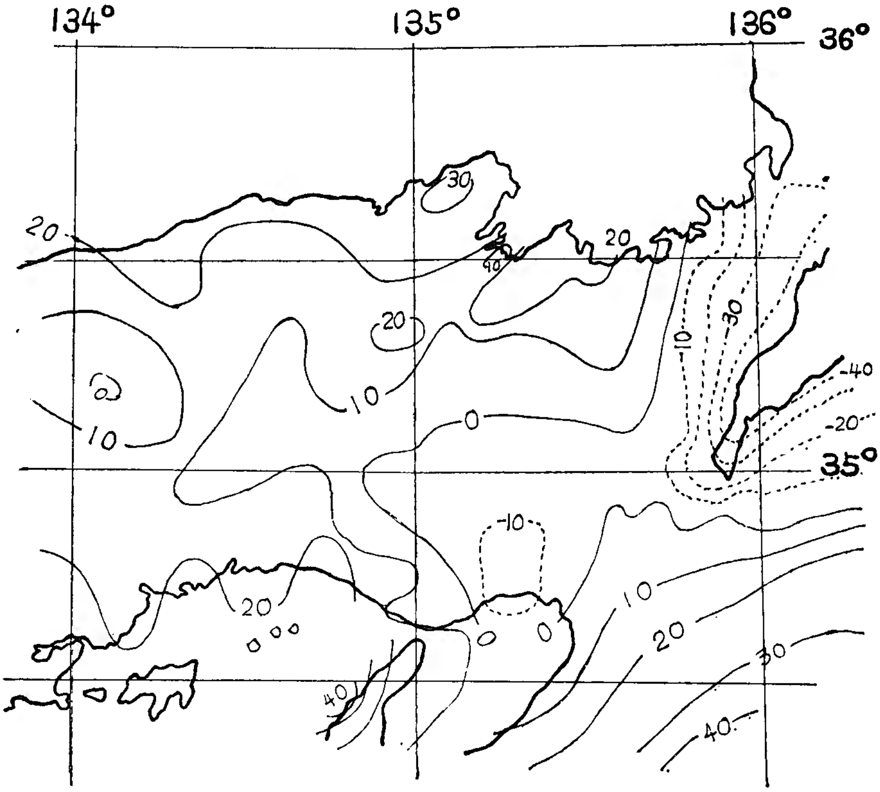


Fig. 9. The distribution of the Bouger anomaly.

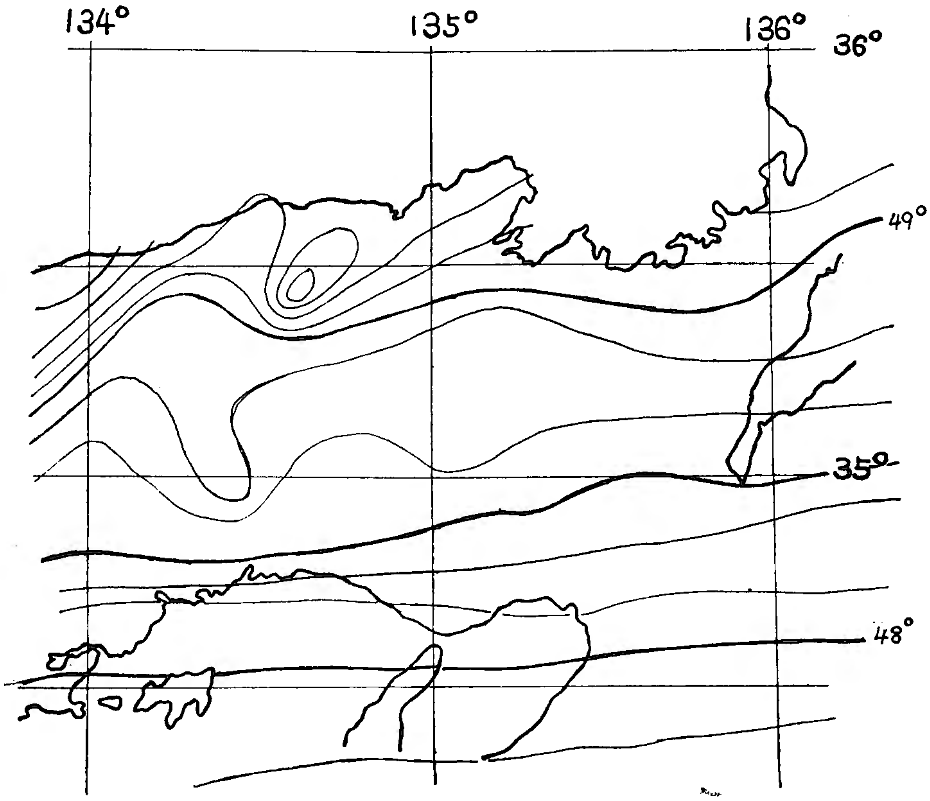


Fig. 10. The isoclinic chart of geomagnetism.